Inventory Management and Facility Layout Design for AXEL Americas

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1.0 Introduction

Founded in Sperry, Oklahoma, Royal Manufacturing has produced lubricants and greases for various industries for over 100 years. In 2018, Royal Manufacturing was acquired by AXEL Christiernsson, becoming AXEL Royal as part of AXEL Americas, LLC. AXEL Americas, also known as AXEL, currently operates manufacturing facilities in Oklahoma, Texas, and Mississippi. The Tulsa, OK facility is the focus of this project. Today, many of AXEL's clients are large oil companies.

1.1 Problem Background

AXEL holds its raw materials and packaging for making grease in a storage facility. Raw materials and packaging, or simply materials, are used interchangeably. Operators must travel approximately 350 feet from the manufacturing facility to the storage facility. The current system for locating inventory relies on the knowledge of the operators. When raw materials are retrieved, the operator must remember and find where those materials are placed. Additionally, the operators place received raw materials in available locations or where they previously placed them. There is no specific assigned location for each SKU. This leads to decreased accessibility and increased retrieval times.

AXEL plans to implement a new inventory management system in 2024 to replace the aging legacy system. While this will help AXEL track quantities of inventory, the team will assist in creating a smoother transition by providing new inventory controls and strategies. This is essential to meet production and demand while balancing inventory costs and storage availability.

1.2 Problem Statement

AXEL has defined two separate, interconnected projects where they seek improvement. The two projects require individually defined problem statements.

- AXEL wants to find a balance between the benefits of having the right amount of raw material and packaging inventory to meet production demand while minimizing the cost of holding the inventory.[1]

- AXEL wants to improve its facility layout and system for storing and locating inventory to prioritize FIFO, accessibility, and safety.

1.3 Objectives, Scope, and Current State Analysis

AXEL has requested that we prioritize the inventory management project. The facility layout redesign and inventory storage system recommendations are secondary projects. The inventory management project is

[1] Inventory holding costs in this case is defined as the product price per unit of each SKU, the rate of return of the S&P 500, and the number of units.

essential to the success of the facility layout design project because the inventory management project determines the ideal amount of inventory on hand. This can ultimately affect the space used and where to place the items.

To fully understand AXEL's current situation, we created a cause-and-effect diagram shown in Figure 1, also known as a fishbone diagram, to show the root causes of the problems. This diagram shows the effects caused by these problems. This diagram also shows factors that contribute to the efficiency of AXEL's current system for storing and retrieving items. An important takeaway from this diagram is getting to the root cause of the problems contributing to inventory management inefficiencies and facility layout. AXEL will then be able to make solutions accordingly.

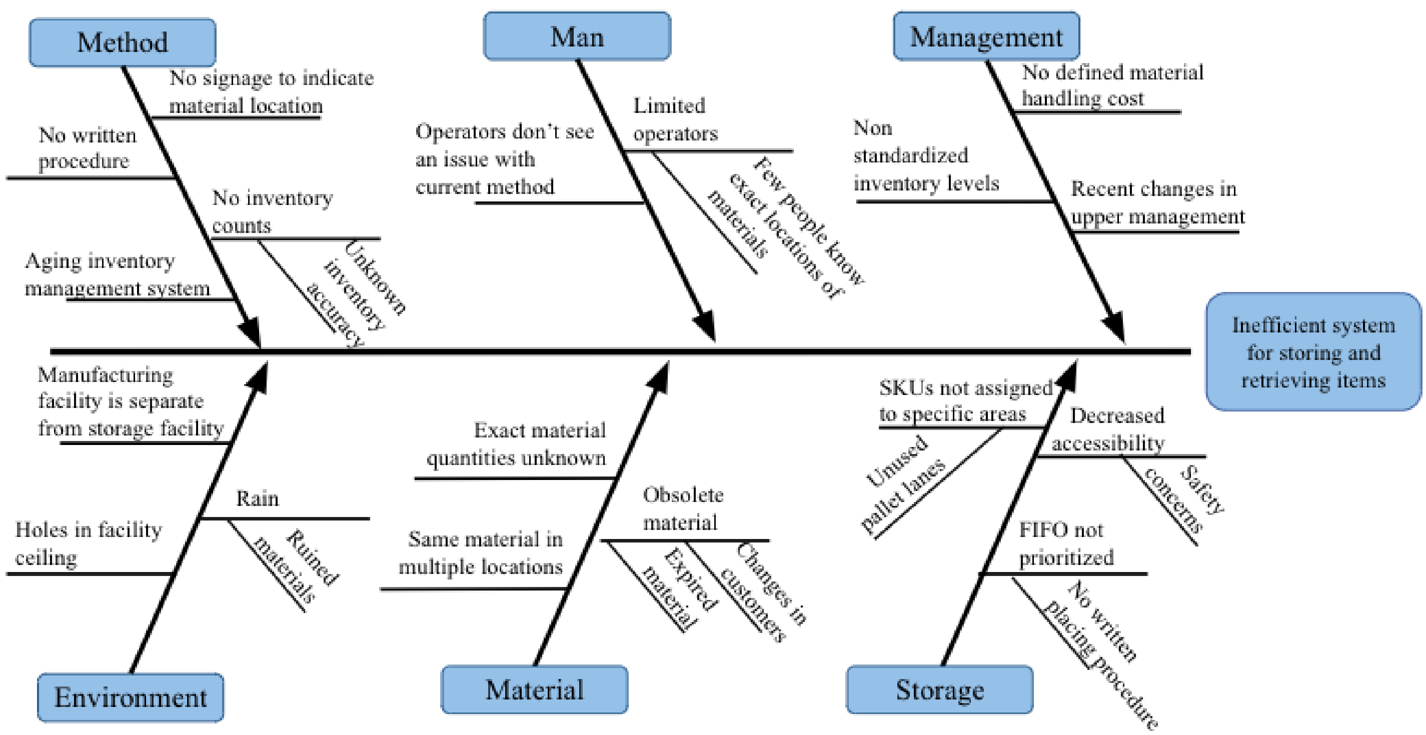

Figure 1: Fishbone Diagram

1.3.1 Inventory Management

AXEL currently uses a legacy inventory management system with a planned upgrade for 2024. While this upgrade may help improve the tracking of materials, it does not tell us the preferred level of available materials at a given time nor where to store them. AXEL wants to balance the cost of storing the inventory against the production demand to ensure customer satisfaction.

Based on demand data, this project aims to define new inventory management strategies to help AXEL determine the amount of inventory on hand. The procurement team will use these strategies to ensure there are enough available materials at any given time to meet production needs. This information includes the safety stock, order quantity, reorder point, and minimum and maximum inventory.

1.3.2 Facility Layout

The focus of the second project is the design of an improved facility layout for the Brooks Building storage facility that will enable increased accessibility for operators. The Brooks Building specifically holds powder materials, raw materials, and packaging for final goods. Another part of the project's focus is the active-use pallets of materials required for current orders and material storage on the second floor of the Grease Plant. AXEL would like the new facility layout to prioritize safety and FIFO; additionally, the layout should decrease retrieval times and create a new system for storing items. Additionally, incompatible and flammable materials should be placed in locations that will mitigate their associated risks and increase safety.

AXEL has indicated that the following were within the project's scope: powder material, trailers, packaging, totes, kegs, and drums for liquids. AXEL also decided that the fixed bulk base oil storage, rework, dead stock, and slow-moving inventory are out of scope.[2] While the fixed bulk base oil storage location was considered out of scope, the order quantity is considered within scope.

2.0 Project Methodology

Our team used the following methodology:

2.1 Understand the Problem

a. Meet with AXEL to discuss overview of project
b. Take a tour of the facility
c. Understand the current state

2.2 Collect Data

a. Receive inventory usage data from AXEL
b. Measure Brooks Building dimensions and distance between facilities
c. Talk with operators to understand issues

2.3 Analyze Data

a. Determine pain points and symptoms of the problems
b. Clean and organize data
c. Make appropriate assumptions
d. Calculate lead times, safety stock, reorder points, and minimum and maximum inventory points
e. Create the current layout of storage areas in AutoCAD

2.4 Develop Alternatives

a. Finalize inventory levels that have a high probability of meeting production needs but keep holding costs down
b. Compute the average inventory and the inventory holding costs

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[2] Fixed Bulk Base Oil Storage: liquid silos located north of the oil plant and west of the grease plant
Rework: finished goods that did not meet order specifications that are incorporated into future batches
Dead Stock: inventory that was required for former clients that can not be used for other clients
Slow-moving Inventory: inventory that has been ordered within the last 6-12 months

c. Perform a sensitivity analysis on different service levels for all inventory calculations
d. Share progress on inventory strategies with AXEL to determine if it meets the criteria
e. Determine potential inventory count systems
f. Design alternative warehouse layout(s) that enable more efficient operations, FIFO, and increased accessibility.
g. Share updated, in-progress layout designs with AXEL
h. Determine which racking, equipment, or other storage systems are necessary

2.5 Evaluate Alternatives and Make Recommendations

a. Complete a cost-benefit analysis for updated inventory levels
b. Complete a cost-benefit analysis of inventory counts
c. Finalize a detailed facility layout design
d. Complete a cost analysis for each facility design alternative
e. Determine the cost of storage equipment

3.0 Data Collection

The following section is divided by project: inventory management and facility layout. Each project required different data and approaches. For the rest of this report, each section is divided with the inventory management project first and facility layout second.

3.1 Inventory Management Data

Currently, AXEL has an aging inventory management system. Furthermore, changes in upper management have led to a desire to update inventory management policies. The data available to our team included part numbers, description, monthly and daily usage, management-defined safety stock, lead times, maximum storage, and turns in inventory over the previous 12 months. AXEL has already used an ABC analysis to classify the SKUs by importance. We provide a further explanation of the analysis in Section 4.1. Additionally, our team received purchase order (PO) data from the previous 12 months, including the order date, date received, and quantity ordered. Most of the currently-used SKUs had at least one PO. The SKUs that are not in use have no monthly or average daily usage.

3.2 Facility Layout

Our team held an initial visit at the AXEL facility to discuss with upper management the problems they see with the current facility layout and procedures for placing and storing materials. During the visit, our team was given a guided tour of the facility. This provided a better understanding of the issues that the management stated during the meeting as well as allowed our team to identify other potential issues. Our team identified some of the potential problems stated below:

- Limited accessibility leading to long retrieval times (reaching too far out, reaching too high)
- No signage to indicate SKU location
- No written procedures for storing inventory
- Slots are stored behind SKU’s
- FIFO is not prioritized
- Potential safety issues
- Potential structural challenges such as the location of pillars and openings in the ceiling

To design a new facility layout, a blueprint of the current layout was required. This was necessary to allow modifications to take into consideration structural elements such as support beams, doors, electrical boxes, etc., that cannot be relocated. Due to the unavailability of this information, our team held a second visit to measure the interior dimensions of the storage facilities.

The second visit also allowed our team to take more pictures. The team also talked to the forklift operator to get their opinion on potential safety issues, with our greatest concern being the risk of pallet stacks falling over. The operator said that he has never had any concerns over the structural integrity of pallet stacks. He also noted that when pallet stacks begin to lean, he will take the time to reorganize them.

4.0 Data Analysis

4.1 Inventory Management Strategy

Inventory management and control strategies are essential to the success of a company. While these strategies look different within each company, good inventory management strategies can help make companies more efficient and avoid lost revenue. One commonly used inventory control strategy is the ABC analysis which typically classifies inventory by the importance of annual dollar usage. Other criteria can be used to classify a SKU's importance, like shelf life or lead times, but the annual dollar usage is the most common. The most important SKUs are given an "A" designation, typically making up 80% of the dollar usage. This designation should be given the highest priority. The second most important classification is given a "B" designation and accounts for 15% of the dollar usage, while the least important classification, "C," accounts for 5% of the dollar usage (Chapman et al).

AXEL has already classified the SKUs based on importance using the ABC analysis. In addition to the "A," "B," and "C" classifications, there were SKUs that had no designation. Based on the data received, these SKUs were not used at all or were used very little over the previous 12 months. These SKUs were not used in the analysis of improved inventory levels, but they will be discussed later in Section 5.1.

4.1.1 Lead Time

Lead time is the time between when an order is placed with a supplier and when the materials from that order are received. In the data that our team received, AXEL has already defined lead times. AXEL also orders the materials 30 days in advance in addition to the already determined lead times with the exception of a few SKUs. We used the predefined lead times in specified calculations that assume there is no variation in the lead time. Our team also received PO data from the previous 12 months. Using the PO data, the team calculated the average lead time and the standard deviation of the lead time for each SKU. Multiple SKUs did not have a predefined lead time, instead, we used the average lead time from the PO data. If the PO data indicated there was no variation in the lead time of a SKU, the lead time was assigned a standard deviation of one day to take into account minimal variation.

Additionally, many SKUs did not have any PO data, so we had to make assumptions about the variation in lead times. To be able to assign lead time variation to these SKUs, we divided them into two groups: predefined lead times of 28 days or less and predefined lead times greater than 28 days. We took the average standard deviation of the lead times of 28 days or less from the PO data. The average standard deviation was assigned as the standard deviation for the SKUs with lead times of 28 days or less. We did this same method for the SKUs with a lead time greater than 28 days but used the average standard deviation from the PO data with lead times greater than 28 days.

4.1.2 Service Level

A company's service level is the probability that a company will have enough inventory to avoid a stockout (Chapman et al). Stockouts are expensive, resulting in unfilled customer orders and therefore lost sales. A service level is defined by upper management and can be changed if the company wishes to change the company's strategy. AXEL has already decided on a service level of 95% at the finished goods level. For this project's scope, AXEL has also defined a service level of 95% for the individual SKUs. Furthermore, some of AXEL's upper management would like a service level of 99% on the raw material level and have the service level vary by the SKUs designation from the ABC analysis. Each service level corresponds with a safety factor from the z score (z) from the normal distribution, as shown in Table 1. The safety factor is a way to quantify the given service level when performing calculations. A safety factor (z) of 1.88 means there is a service level of 97%. Additionally, a service level of 97% indicates a 3% chance of having a stockout or not having materials when needed.

Table 1: Service Levels

Service Level	**Safety Factor (z)**
95.0%	1.65
95.5%	1.69
96.0%	1.75
96.5%	1.81
97.0%	1.88
97.5%	1.96
98.0%	2.05
98.5%	2.17
99.0%	2.33

4.1.2 Safety Stock

Safety stock, or buffer stock, is the amount of additional inventory a company has stored to ensure that demand can be met during the lead time (Association for Supply Chain Management). Safety stock increases customer satisfaction by meeting customer demand even when demand and lead time fluctuate. On the other hand, safety stock inventory can negatively affect operating expenses as it increases the amount of inventory being stored, therefore increasing the cost of holding inventory. Safety stock serves as a foundation for calculating the reorder point, maximum inventory, and minimum inventory for each SKU.

Most of the products produced by AXEL have constant demand all year; therefore, it is assumed that the raw materials and packaging have constant demand. This constant demand indicates that there is little to no variation in the usage of each SKU.

There are multiple methods for finding safety stock that depend on the information that is available. Simpler methods that do not use variation in demand or lead time can provide a reasonable estimate. Still, those methods do not consider fluctuations that might make it difficult for a company to meet production needs. After evaluating multiple methods, we chose to focus on one specific method because it had the most consistent inventory levels for all SKUs. This method relies on variation in demand and lead time. While the demand is constant and has no variation, the lead time varies based on PO data from the previous 12 months. A stochastic model provides the best approximation given the previous assumptions. Using a stochastic model to determine the safety stock assumes that the demand during the lead time can be covered with high probability. The stochastic model takes into account uncertainty that could affect the demand over the lead time.

The standard deviation of lead time was calculated from the PO data received from AXEL and the average lead time came from AXEL's predefined lead time. The following formula calculates each SKU's safety stock, S, using the lead time and demand of that specific SKU (Liu). 'S' is the safety stock, 'z' is the score for a given service level, 'σ_D' is the standard deviation of demand, 'σ_L' is the standard deviation of lead time, 'μ_D' is the average daily demand, and 'μ_L' is the average lead time.

$$S = z * \sqrt{\sigma_D^2 \mu_L + \sigma_L^2 \mu_D^2}$$

4.1.3 Reorder Point

The reorder point in inventory management indicates when an order should be placed to ensure that demand is met and reduces the likelihood of not having materials available when needed. The reorder point is built upon the safety stock and is dependent on the service level. The reorder point is calculated on the individual SKU level. The formula below calculates the reorder points, s (Liu). 's' is the recorder point, μ_D is the average daily demand, 'L' is the lead time, 'r' is the review period, and 'S' is the safety stock.

$$s = \mu_D * (L + r) + S$$

4.1.4 Minimum Inventory Levels

The minimum inventory level represents the lowest amount of material that should be kept to ensure that demand is met. Both the minimum and maximum levels of inventory are determined by the safety stock. The minimum level of inventory is simply the safety stock of SKU found in Section 4.1.2.

$$minimum\ inventory = safety\ stock$$

4.1.5 Maximum Inventory Levels

The maximum inventory level ensures that demand can be met while also minimizing the holding cost. Determining the maximum level of inventory requires knowing the order quantity. Since the PO data has varying quantities ordered during the previous 12 months, the maximum quantity ordered was used as the order quantity. If the maximum quantity was an outlier, then the highest order quantity that was not an outlier was used instead. The formula below calculates the maximum inventory. Additionally, a sensitivity analysis can be performed for the maximum inventory as it relies on the service level used to find the safety stock. 's' is the reorder point in units and 'Q' is the order quantity in units.

$$maximum\ inventory = s + Q$$

The maximum inventory is limited by the space available and inventory holding costs. Due to the time limits with this project, we were unable to determine the space requirements for the maximum amount of inventory. The inventory level should never exceed the maximum inventory level, because that increases the inventory holding costs and could be economically disadvantageous for AXEL.

4.1.6 Average Inventory

The average inventory is useful information for calculating inventory holding costs. The average inventory can provide information on the consumption rate of materials and help companies understand if the inventory can meet production demands. In this project, we are solely using the average inventory as a method of evaluating different service levels and the inventory holding costs. We will not be providing any recommendations based on the average inventory. The following formula can be applied to determine the average inventory for each SKU (Liu). 'Q' is the quantity ordered in units and 'S' is the safety stock.

$$Avg.\ Inventory\ =\ Q/2\ +\ S$$

4.1.7 Inventory Holding Costs

Storing inventory incurs a cost to a company. Inventory holding costs directly affect the profitability of a company by increasing a company's operating costs. It is important to minimize inventory holding costs while still having enough inventory available to meet production needs. There are a variety of methods for calculating inventory holding costs, but we found the holding cost by computing the opportunity cost. This calculation can be viewed as the equivalent cost of investing the expected cost of inventory into the stock market rather than storing the inventory itself.

For the purpose of this project, we found the 40-year average return of the S&P 500 for the rate of return on investment, which was 8.62%[3]. A further explanation of how the rate of return was computed can be found in Appendix A. To evaluate the holding cost per SKU, we used the average inventory found in Section 4.1.6. The cost per unit was data that we received from AXEL that they have defined. 'R' is the rate of return set to 8.62%, 'C' is the dollar cost per unit, and 'N' is the number of units.

$$Inventory\ holding\ cost\ =\ (1\ +\ r)\ *\ C\ *\ N$$

A sensitivity analysis on the inventory holding costs at different service levels is performed in Section 5.1.1 to evaluate the costs of holding different amounts of inventory of the same SKU.

4.2 Facility Layout

4.2.1 Facility Dimensions

Using the dimensions of AXEL's Brooks Building, we evaluated the current state of the facility. The team approached this by making AutoCAD drawings that can be used to visualize the space. The drawing for the Brooks Building is shown in Figure 4.

[3] 40-year annual geometric mean return of the S&P 500 using end-of-year returns. Data is from the Center for Research in Security Pricing, LLC (CRSP), an affiliate of the University of Chicago Booth School of Business.

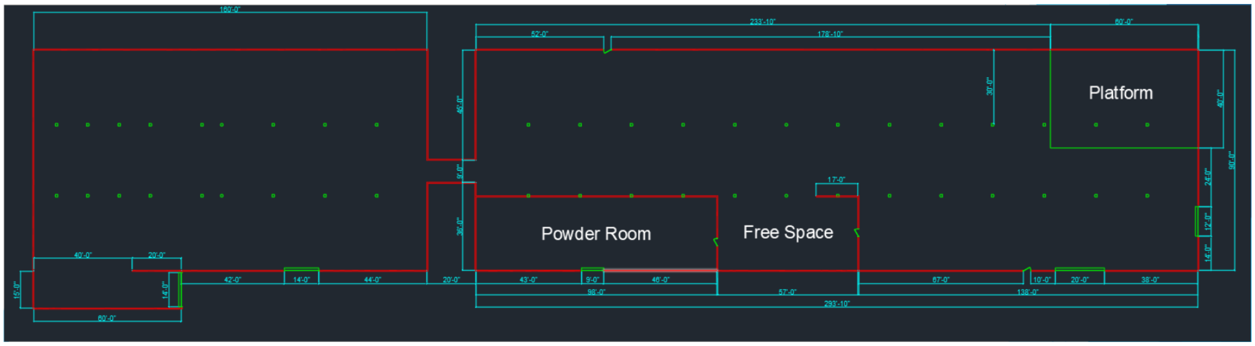

Figure 4: Brooks Building Dimensions

4.2.2 Safety Concerns

As the team collected the dimensions throughout AXEL facilities, we came across some safety concerns that should be considered by AXEL. These safety concerns include unstable stacks of pallets, inadequate spacing of pallets, and the presence of holes in the ceiling of the Brooks building that could result in damage to raw materials and damage to the pallets that are holding these raw materials. By ensuring these concerns are addressed, AXEL will be complying with OSHA regulations to mitigate the risk of a safety violation. OSHA safety regulations for pallet stacking can be found in Appendix B.

5.0 Solution Alternatives

5.1 Inventory Management Alternatives

5.1.1 Inventory Levels

The primary goal of this project was to determine the levels of inventory required to meet customer demand.

A sensitivity analysis of the safety stock shows how different service levels affect the amount of safety stock required. At times, AXEL has established that they would like to have a service level of 95%, and at other times, they have expressed the desire to have a service level of 99%. AXEL has also indicated that they would like to have different service levels based on the ABC analysis they determined. Below, we provide multiple alternatives for analyzing differences in service levels and inventory levels.

<u>Same Service Level for all SKUs</u>

AXEL initially stated that they had a 95% service level for their raw materials. Based on this information, we initially found all inventory levels at a 95% service level. This is a simple solution to determining the service levels for all SKUs. Example calculations for this specific service level are included above in Section 4.1. The inventory holding costs for all SKUs at a 95% service level is about $6,470,000. The “A” SKUs account for the majority of the inventory holding costs in this method since those SKUs also account for the highest annual dollar usage.

<u>Service Level by ABC Analysis</u>

Using the ABC analysis as a guide for determining service levels ensures that the most important SKUs are given the highest priority. The SKUs that have the highest priority should have a service level that is higher than SKUs that do not have as high of a priority (i.e., the service level for “A” SKUs is higher than “B” SKUs which is higher than “C” SKUs). We completed sensitivity analyses for each ABC designation with the associated service levels. Table 2 specifies the specific service levels per the ABC designation (Lokad). We used the same formulae to calculate all the inventory levels from the previous section.

Table 2: ABC Recommended Service Levels

ABC	Service Levels
A	95% - 99%
B	90% - 95%
C	85% - 90%

Part number C012 has an "A" designation. Figure 5 shows the sensitivity analysis of that part number from 95% - 99% service level in 0.5% intervals. Note that safety stock is measured in units.

	Safety Stock = Minimum Inventory								
Part #	95.00%	95.50%	96.00%	96.50%	97.00%	97.50%	98.00%	98.50%	99.00%
C012	14988.95	15449.53	15953.36	16511.27	17138.98	17860.43	18715.06	19775.23	21199.15

Figure 5: Sensitivity Analysis of "A" SKU Safety Stock

Part number C005 has an ABC analysis designation of "B." We performed a sensitivity analysis from 90% - 95% in 0.5% service level increments.

	Safety Stock = Minimum Inventory										
Part #	90.00%	90.50%	91.00%	91.50%	92.00%	92.50%	93.00%	93.50%	94.00%	94.50%	95.00%
C005	30.45	31.14	31.86	32.61	33.39	34.21	35.07	35.98	36.95	37.98	39.09

Figure 6: Sensitivity Analysis of "B" SKU Safety Stock

For part number C0452, it has a "C" designation from the ABC analysis. We performed a sensitivity analysis from 85% - 90% in 0.5% increments.

	Safety Stock = Minimum Inventory										
Part #	85.00%	85.50%	86.00%	86.50%	87.00%	87.50%	88.00%	88.50%	89.00%	89.50%	90.00%
C0452	333.38	340.36	347.50	354.81	362.32	370.02	377.95	386.11	394.53	403.22	412.23

Figure 7: Sensitivity Analysis of "C" SKU Safety Stock

The average inventory is an essential input to the inventory holding cost formula. An example calculation can be found in Section 4.1.6 for average inventory and Section 4.1.7 for inventory holding cost. We performed a sensitivity analysis on the average inventory for part number C012 with a designation of "A." The sensitivity analysis refers to the service level used to find the safety stock. These analyses are found in Figure 8 and Figure 9.

	Average Inventory								
Part #	95.00%	95.50%	96.00%	96.50%	97.00%	97.50%	98.00%	98.50%	99.00%
C012	18244.46	18705.05	19208.87	19766.79	20394.49	21115.94	21970.57	23030.75	24454.66

Figure 8: Sensitivity Analysis of "A" SKU Average Inventory

	Holding Cost								
Part #	95.00%	95.50%	96.00%	96.50%	97.00%	97.50%	98.00%	98.50%	99.00%
C012	$ 111,903.37	$ 114,728.42	$ 117,818.65	$ 121,240.66	$ 125,090.72	$ 129,515.78	$ 134,757.68	$ 141,260.34	$ 149,994.01

Figure 9: Sensitivity Analysis of "A" SKU Inventory Holding Cost

While the increments in all the sensitivity analyses are the same, that does not necessarily mean that values increase at the same rate (linearly). The values in each sensitivity analysis correspond with a service level. The service level has a safety factor which comes from a z-score from the normal distribution (see Table 1). As the service level becomes higher, the z-score also gets larger, but not at a constant rate of change.

The difference between the inventory holding costs for the highest and lowest service levels is greatest for the "A" SKUs, because they have the highest annual dollar usage. The difference between the 95% and the 99% inventory holding costs is about $1,150,000. The greatest increase in inventory holding costs comes between the 98% to 99% service levels. The difference between the highest and lowest for inventory holding costs for "B" and "C" SKUs is about $95,000. If each of the highest service levels of the sensitivity analysis is used, the total inventory holding cost is estimated to be $7,600,000. If the service level for the "A" SKUs is lowered to 97.5%, but the "B" and "C" SKUs remain the same, the total holding cost would be reduced to about $6,950,000.

5.1.2 Inventory Counts and Inventory Accuracy

Currently, AXEL does not have an inventory count system in place for the majority of the raw materials and packaging. An inventory count physically tracks inventory and helps update inventory records to ensure they are accurate. Inventory counts help customer satisfaction by making sure the inventory levels meet production demand while still fulfilling customer orders. AXEL intends to implement an inventory count system for all their raw materials and packaging next year. While inventory counts can be tedious and time-consuming, they can provide meaningful information on the accuracy of the inventory.

Many companies hire additional workers or contract workers to perform inventory counts rather than devoting their current resources to it. This can be costly. We evaluated the following four methods for inventory counts: ABC analysis I and II, annual inventory count, and no inventory count. Fortunately, AXEL's inventory at this facility is not too large, so hiring extra workers or contract workers to complete the inventory counts for each of the four methods discussed below would not be necessary.

<u>ABC Analysis Inventory Count I</u>

The first inventory count method we evaluated relies on the ABC analysis that AXEL originally provided. The SKUs with the "A" designation should be given the highest priority and should be counted most frequently throughout the year. For this method, the "A" SKUs should be counted monthly (12 times per year). In this case, AXEL should strive to have 100% accuracy on "A" SKUs. The "B" SKUs should be counted quarterly (4 times per year) with an accuracy of 98%. The "C" SKUs should be counted once per year with a target accuracy of 95%. This method incurs the highest labor cost but provides the greatest accuracy. Additionally, AXEL counts the SKUs with the highest priority often enough that if there are discrepancies in the inventory, they would have enough time to take corrective actions to reduce the likelihood of a stockout and ensure customer demand is met.

Based on the ABC analysis performed by AXEL, there are 55 active "A" SKUs, 108 "B" SKUs, and 162 "C" SKUs. We hypothesize that it takes eight minutes, on average, to count a SKU. This could be more or less than eight minutes. The average full-time employee works 2,000 hours per year. In Table 2, we show the total hours spent on inventory counts by SKU priority. The total labor hours devoted to inventory counts using this method is 167.2 hours, which is 8.36% of the total yearly labor hours.

Table 3: ABC Analysis I

ABC	# of SKUs	Counts/year	Labor hours/year
A	55	12	88
B	108	4	57.6
C	162	1	21.6

<u>ABC Analysis Inventory Count II</u>

The second inventory count method we evaluated is also based on the ABC analysis. In this method, the SKUs that have been designated with an “A” should be checked three times per year; furthermore, these counts should be spaced evenly throughout the year. AXEL should aim for 100% accuracy on the raw materials counts. The SKUs with a “B” designation should be counted two times per year with 98% accuracy, and the “C” SKUs can be counted once per year with 95% accuracy. While the labor cost might be higher than the following two methods, it allows for greater accuracy. Additionally, if an order of materials is much less than was anticipated, the company can complete corrective actions before it affects production. If there appear to be mismatches between the physical inventory and what the ERP system states, AXEL can identify the discrepancies and take action to correct the mismatch.

As mentioned in the previous ABC Analysis Inventory Count, there are currently 55 “A” SKUs, 108 “B” SKUs, and 162 “C” active SKUs. Again, we hypothesize that it will take, on average, eight minutes to count each SKU. Eight minutes could be an overestimate or an underestimate of the actual time needed to count a SKU. The average full-time employee also works 2,000 hours per year. Table 3 shows the labor hours to perform inventory counts per SKU per year, which is roughly 79.7 total hours. This is roughly 4.0% of the total yearly labor hours.

Table 4: ABC Analysis II

ABC	# of SKUs	Counts/year	Labor hours/year
A	55	4	29.3
B	108	2	28.8
C	162	1	21.6

<u>Annual Inventory Count</u>

Another method for performing inventory counts is by completing the counts annually. This method neglects the priority given to the SKUs that have a higher annual dollar usage and priority. Since this method would only happen once a year, AXEL would not need to necessarily hire or contract additional workers to complete the inventory counts. In this method, AXEL would not be able to provide corrective action as frequently as the previous method when inventory levels are not accurate. If these corrective actions come too late, AXEL might be unable to fulfill customer orders, leading to customer dissatisfaction, decreased reputation, and decreased sales revenue.

There are currently 325 active SKUs. If each SKU is only counted once per year at a rate of 8 minutes per SKU, an employee would devote 43.3 hours (2,600 minutes) to count all the inventory. This is 2.17% of the total 2,000 hours worked per year. The employee could count between 27 and 28 SKUs per month or one to two SKUs daily.

No Inventory Count

Lastly, AXEL can choose not to implement any of the previously mentioned inventory counts. While this would minimize the labor costs associated with performing inventory counts, not knowing whether the inventory is accurate can cause potential problems. If the inventory is consistently inaccurate, AXEL would have to take corrective actions when it might be too late to get the raw materials needed to meet production. Having no inventory counts could cause unfilled customer orders and potentially decrease expected sales revenue; additionally, this could cause AXEL to order more raw material than needed to ensure there is enough inventory or cause some uneasiness with employees about whether there is enough material to meet production demand. It is difficult to determine the cost of lost sales due to unfilled orders. We were not able to quantify this cost as it varies from year to year and requires additional data that might not be available to AXEL.

5.2 Facility Layout Solutions

Our team designed four sets of alternative layouts for the Brooks Building. Each set contains two alternative layouts that use the same racking or pallet lane system; the latter layout in each set removes the walls used to form the Powder Room and the adjacent room.

Each rack has three levels, each being able to hold two pallets. The dimensions of these racks are 108 inches wide, 42 inches deep, and 120 inches tall. The racks have a weight capacity of 20,000 lbs, with each level (pair of support beams) having a capacity of 10,000 lbs. These should be able to accommodate the majority of the pallets that AXEL stores in the Brooks Building.

Each pallet lane is three pallets deep and is capable of storing upwards of nine pallets if stacked three high.

5.2.1 Solution Analysis

After designing the alternatives, we needed to compare them in order to determine which would be the best to implement. In order to compare them, we calculated the number of pallet racks/lanes, the number of pallet slots, the cost to implement, and the cost per slot. These calculations are shown in Figure 10. These costs are based on information collected from ULINEs company website; the implemented cost also considers the basic bulk pricing plan listed on their website. The Excel files containing the racking price research and the alternatives analysis are included in this report.

Alternatives	# of Pallet Racks/Lanes	# of Available Slots	Cost to Implement	Cost Per Slot
[1] Single-Deep Pallet Racking (w/ walls)	215	1,290	$193,038.00	$149.64
[2] Single-Deep Pallet Racking (w/o walls)	232	1,392	$207,659.00	$149.18
[3] Double-Deep Pallet Racking (w/ walls)	284	1,704	$253,963.00	$149.04
[4] Double-Deep Pallet Racking (w/o walls)	320	1,920	$285,965.00	$148.94
[5] Mixed-Depth Pallet Racking (w/ walls)	290	1,740	$223,696.00	$128.56
[6] Mixed-Depth Pallet Racking (w/o walls)	309	1,854	$236,321.00	$127.47
[7] Pallet Lanes (w/ walls)	203	609 (1,827 max)	$875.00	$0.48
[8] Pallet Lanes (w/o walls)	213	639 (1,917 max)	$925.00	$0.48

Figure 10: Alternative Solution Calculations

In order to gain a better understanding of the information shown in Figure 23 and of the alternatives, the sections below break down how the costs were found and other factors that needed to be considered.

For the alternatives that use pallet racking, the cost to implement includes only the materials required to build the racks. These include rack starters, rack add-ons, decking row spacers, flue guards, rack protectors, and installation kits. The pricing does not take into consideration the installation cost, shipping cost, wall demolition costs, and forklift costs; it is important to note that pallet racking alternatives may only require some of these additional costs. The additional costs were not included as they either required quotes from companies to determine or were difficult to find online. Alternatives 2, 4, 6, and 8 consider the idea of removing the interior walls of the Brooks Building, so the cost of demolition needs to be included. Based on the images of AXEL's forklifts that we received, it looks like AXEL does not have a forklift that can be used for double-deep pallet racking. This means that for Alternatives 3 through 6, which use double-deep pallet racking, the additional cost of a new forklift also needs to be considered.
For the alternatives that use pallet lanes, the cost to implement includes only the cost of the paint. The pricing does not take into consideration the cost of preparing the floors for painting. As stated in the previous paragraph, Alternative 8 will also need to consider the demolition cost of the wall.

The alternatives that use pallet lanes have two sets of numbers for the number of slots. The first number is the amount of slots if each pallet lane only holds one layer of pallets. The second number is the amount of slots if each pallet lane holds a full three layers of pallets. Ideally, each pallet lane should only hold one SKU of inventory; this means a pallet lane system would be unable to hold all of the SKUs that AXEL has in their inventory. It is also important to note that even if there was a lane for each SKU, it is likely that each lane would not be able to use its full capacity, resulting in honeycomb loss. This could be countered by allowing the storage of a few SKUs per slot, bringing each lane closer to max capacity. The issue with this is the ease of accessibility. In Alternatives 7 and 8, in order to get the least accessible pallet in a pallet lane that is at max capacity, it would require the movement of 8 additional pallets. This could significantly increase the average retrieval time. The double-deep pallet racks used in Alternatives 3 through 6 store pallets in two pallet-deep lanes that would require at most one pallet to be moved to access the furthest back pallet. Pallet rack systems that only use single-deep racking have no accessibility issues, as all of the pallets are immediately accessible.

AXEL currently uses walls in their warehouse to divide the available space, reducing the efficiency of the space for storage purposes. In hopes of improving space usage, removing these walls can make way for more flexibility within the facility layout. AXEL would first need to determine if these walls are load-bearing. If so, Alternatives 2, 4, 6, and 8 would not be viable as they rely on removing the walls. If they are not load-bearing, then the walls can be removed to use the space more efficiently; the removal of the walls would require anything being stored in these rooms to be relocated. When our team conducted the initial visit, we noticed that there was ample space not being used in the loft in the same warehouse. This space could be a suitable location to relocate those items and store other long-term items within the Brooks Building. Due to the age of the loft, AXEL would need to ensure that it has the structural integrity to handle anything stored on it. AXEL would also require a forklift capable of lifting the items up to the loft.

6.0 Final Recommendations

6.1 Inventory Management Recommendations

6.1.1 Inventory Levels

AXEL's supply chain manager has indicated that having a 95% service level is relatively high.[4] Additionally, a service level of 99% dramatically decreases the probability of a stockout, but it is also more expensive to maintain, especially on the "A" SKU level. It is important for AXEL to prioritize the SKUs that have an "A" designation but also minimize the cost of holding inventory.

It is important to note that a service level of 95% does not mean that there is a 95% chance that there is some material in inventory. We used a service level on all inventory levels calculations. If there is a certain demand for a certain material, there is a 95% probability that the needed material will be available in inventory.

We recommend that AXEL use the sensitivity analysis based on the ABC analysis and the appropriate service levels rather than a 95% service level for all SKUs. In this method, the most important SKUs have the highest service level and priority. We further this recommendation by suggesting that AXEL use a 97.5% service level for the "A" SKUs. By going higher than that service level, the inventory holding cost greatly increases. A 97.5% level is still high. In reality, a 99% service level is highly unfeasible due to costs and the difficulty to maintain. If AXEL decides to use a 95% service level for "B" SKUs and a 90% for "C" SKUs with a 97.5% for "A" SKUs, AXEL would incur a 7.3% increase in the inventory holding cost from the 95% service level for all SKUs.

6.1.2 Inventory Counts and Inventory Accuracy

By evaluating the four different alternatives for inventory counts, our team recommends that AXEL implement the ABC Analysis Inventory Count I, which suggests 12 "A" counts, four "B" counts, and one "C" count per year. Being able to meet demand and having raw materials available for production is of high importance for AXEL. The inventory counts using the ABC analysis will help AXEL give priority to the material they have determined to be the most important. Additionally, if there are issues with inventory accuracy, AXEL will be able to take corrective actions to have enough raw material available to meet production needs. While this is the most expensive and time-consuming option, customer demand can be met ensuring increased customer satisfaction and retention; and meeting expected profitability. While the labor time required for one person to complete all counts per year is about 8.36% for this method, which is a 110% increase in time from the other ABC analysis inventory count method (4.00% of total labor time). These percentages come under the assumption that it takes eight minutes to count a SKU. Though this percent increase implies that it takes almost double the labor time to complete the additional inventory counts, the trade-off allows AXEL to have better control over the inventory because they can fix discrepancies before it is too late to fix. Additionally, this method provides the most excellent

[4] Note that having a 95% service level for 10 raw materials that make a certain product does not necessarily mean that the service level for the finished goods is 60% (0.95^10); furthermore, this does not indicate there is a 40% probability of a stockout.

transparency and visibility on the inventory. Having inventory counts and better visibility on inventory will help assuage fears associated with some discrepancies in the lead times.

6.1.3 Lead Time Review and Demand Variation

There are many discrepancies based on the lead times determined by the company and the average lead times calculated from the PO data. The lead times that were already determined do not include the 30 review period, which allows for increased supplier visibility and decreases the number of POs. The average lead times from the PO data should already include the 30 review period. The average lead time is still often less than the predetermined lead times. With supply chain issues over the previous three years, we recommend recalculating the lead times to have a better estimate of lead times. Lead times and the variation in lead times directly affect the safety stock, minimum and maximum inventory levels, and the reorder point. An accurate lead time will help better estimate the previously mentioned inventory management calculations to meet demand requirements and service levels.

In addition to reviewing the lead time, we recommend that AXEL evaluate the variation in demand. Though demand is constant, nothing can be perfectly constant. AXEL can still determine the variation in demand, even if it is very small. Many safety stock formulae require a quantified demand variation. By reviewing both the lead time and the variation in demand, the computations for safety stock, reorder point, and maximum and minimum inventory levels will be more accurate to the actual lead time and demand variation that AXEL has.

6.1.4 Other Data Review

While the data in Section 6.1.3 are crucial to finding safety stock and all the calculations that rely on safety stock, additional data should be reviewed to calculate inventory holding costs better. There are some SKUs that have a cost of $0.00. AXEL should review the cost per SKU for the SKUs that don’t currently have a cost. The cost per unit plays an essential role in calculating the holding cost. Missing data makes it more challenging to evaluate the inventory holding cost accurately.

In addition to the cost per unit, we recommend that AXEL define the order quantity per SKU. We provided an estimate by looking at the PO data from the previous 12 months by taking the highest quantity ordered per SKU. Some SKUs did not have PO data, so we could not provide estimates for the order quantity. In this case, we used the MOQ, which often provided a reasonable estimate for an order quantity. The order quantity is used in calculations for the maximum inventory and average inventory calculations. Reviewing the order quantity will help AXEL have better maximum inventory levels and provide more information on the inventory holding cost.

6.2 Facility Layout Recommendations

6.2.1 Proposed Layout

Our team recommends that AXEL blends our layout designs for the mixed pallet rack system and the pallet lane system. We know that some SKUs would be better stored in pallet racks while others are better stored in pallet lanes. Items like grease tube caps that AXEL has multiple pallets of would fit better in pallet lanes. Items that AXEL might have a single pallet for or are not full pallets would work better in pallet racks. Another example would be to store a SKU with a large number of pallets in a pallet lane. We were unable to determine this based on the data that was provided. We recommend that AXEL determine this to implement the proper amount of pallet racks and pallet lanes in the facility.

6.2.2 Labeling System

AXEL can look into incorporating a labeling system in their warehouse to keep track of where raw materials and packaging are located within the warehouse. This would include aisle markers, pallet lane labels, and pallet racking labels. Labeling will differ depending on the type of layout. In the pallet racking layout, it would be effective to use aisle markers and labels on the racks that indicate what individual item goes in that rack. In the pallet lanes layout, it would be effective to paint a number and letter combination on the ground in front of the pallet lane that will indicate a particular item goes in that lane.

6.2.3 Roof Repair

After reviewing pictures of the Brooks Building annex from the initial visit, the team noticed openings in the ceiling that are resulting in exposure to outside elements. During our second visit to gather dimensions of the layout, we noticed that the annex had standing water on the floor as a result of a storm earlier in the day. If these openings were to remain, it could lead to more damaged materials and pose a safety hazard. These openings should be sealed to mitigate these material and safety risks. Our team is also concerned with the age of the building; because of this, there could be more leaks beyond just the openings in the roof. If the building does have an issue with leaks, AXEL may want to consider an entire roof replacement.

7.0 Benefits

7.1 Benefits from Inventory Management Strategies

7.1.1 Inventory Level Benefits

Implementing new inventory management strategies can lead to many benefits for a company. By creating concise inventory levels, AXEL can ensure that demand can be met, even in times when there is potential uncertainty in supply chains and demand. Additionally, by being able to fulfill customer orders due to a sufficient supply of materials, AXEL will be able to maintain customer satisfaction, reputation, sales, and revenue.

7.1.2 Inventory Counts

By implementing inventory counts, AXEL can have better control over stored inventory. Accurate inventory is essential to a company's operations to ensure that the company can meet customer demand. Inventory counts will decrease the amount of obsolescent material, which will increase the available space. If there are discrepancies in the inventory, AXEL can then take action to resolve the discrepancies in a timely manner.

7.1.3 Lead Time and Demand Updates

By updating the lead times and the variation in demand, AXEL can have better estimates for the inventory levels. A better estimate of lead times will give AXEL greater visibility with suppliers and lessen the likelihood of late deliveries. Late deliveries of raw materials can affect AXEL's ability to meet production demand. Accurate lead times will help decrease costs from having too much or too little inventory on-hand and operational efficiencies.

7.2 Benefits from the Facility Layout Plan

7.2.1 Accessibility

The new facility layout plan will provide AXEL with increased accessibility. In AXEL's current layout, pallets are stacked in a way that makes them difficult to reach. The new layout design will solve those types of AXEL's problems regarding accessibility. Another way to provide better accessibility is by following OSHA's regulations regarding pallet stacking height. These regulations are shown in Appendix B. Although pallet lanes do not provide the best accessibility, a balance can be found between the number of pallet racks and lanes that reduces the likelihood of accessibility issues. The combination of labeling in the facility and accessibility of pallets will reduce average retrieval times.

7.2.2 Safety

Safety is a major benefit of the proposed facility layout plan. The redesign of the facility layout, implementing pallet racking or pallet lanes, and fixing the holes in the ceiling of the facility will help eliminate the potential for accidents. The proposed change of using pallet racks or pallet lanes will help AXEL stay within OSHA regulations for pallet stacking which will increase safety within the facility. Also, repairing the roof will help mitigate the risk of a safety violation by keeping the floors dry and safe to work on. The roof repair will also eliminate the chance of inventory and pallets being damaged from rainfall, allowing for any materials to be stored in the annex of the Brooks Building. These safety benefits will be incredibly valuable to AXEL in the future.

7.2.3 Space Utilization

Space utilization is also a key benefit of the facility layout plan. A major issue the team encountered at both visits to the AXEL facility was due partially to honeycomb loss. The recommended solutions significantly improve the utilization of the space in the warehouse. This will result in an increased number of pallet racks/lanes and in turn, an increased number of pallet slots in the Brooks Building.

7.2.4 Implementation of ERP System

Another benefit of the facility layout redesign is that it will be cohesive with whatever new inventory management system AXEL plans to implement in 2024. This new layout will allow for better organization as they make the switch to an inventory management system that will keep better track of the inventory that AXEL has in their facility.

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Appendix A: Rate of Return

Geometric Mean Formula for the Average Rate of Return:

$$\sqrt[n]{\prod_{i=1}^{n} x_i} - 1 = \sqrt[n]{x_1 * x_2 * \ldots * x_i} - 1$$

where,

n = # of terms

x_i = rate of return + 1

The motivation behind using the geometric mean, also known as the compounded annual growth rate, for the average return rather than the mean is it takes into account the compounding of the annual return rate. The geometric mean is always less than the arithmetic mean unless the returns are equal every year. The arithmetic mean often provides an overestimate when the variation/volatility is high. The geometric mean does not evaluate the returns based on the volatility of the returns.

Appendix B: OSHA Regulations
Warehouse Stacking Regulations:

- There is a 20-foot maximum stacking height if stacks are stacked by a forklift
- Pallets must be evenly distributed
- Maintain sufficient clearance around stacks. This will allow for easy access to the stacks.
- Pallet stacks must be stable and self-supporting
- If boxed items are on the pallets these items should be secured with shrink plastic or cross ties.

These are a few points that the team feels directly impact AXEL's facility. The full handbook of OSHA regulations can be found in the references section. If more clarification is needed, the OSHA handbook goes into a more in-depth explanation of the regulations.